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(71) Applicant (*for all designated States except US*): **SAES GETTERS S.P.A.** [IT/IT]; Viale Italia, 77, I-20020 Lainate (IT).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): **DI GREGORIO, Pierattilio** [IT/IT]; Via Margherita, 15, I-67039 Sulmona (IT).

(74) Agents: **ADORNO, Silvano**; Società Italiana Brevetti S.p.A., Via Carducci, 8, I-20123 Milano et al. (IT).

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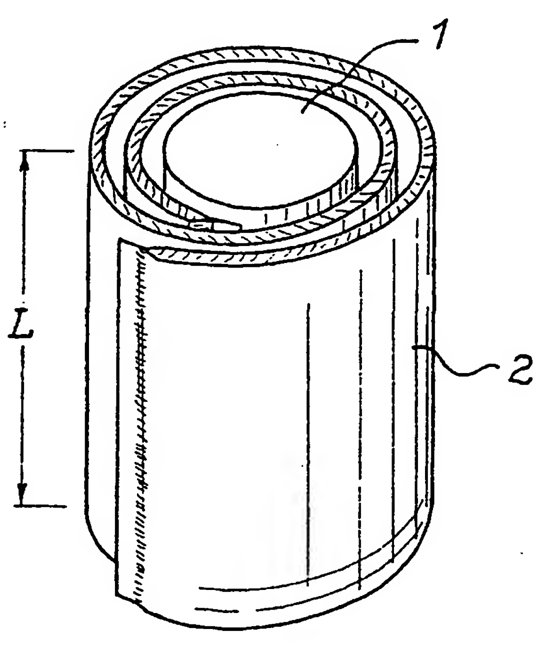

(57) Abstract: An evacuated panel (2) is described, which enables the thermal insulation of a cylindrical body (1), provided with two substantially rectangular main faces and formed of a flexible envelope (4) made of one or more barrier sheets, containing a discontinuous or porous, inorganic or polymeric filling material (3). The panel has a thikness such that the ratio between this thickness and the minimum bending radius of the lateral wall of said cylindrical body is small enough so as to enable the rolling of the panel without compromising the integrity thereof, and length such that it allows at least two rollings around the body (1).

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"EVACUATED PANEL FOR THERMAL INSULATION OF CYLINDRICAL BODIES"

The present invention relates to an evacuated panel which enables the thermal insulation of a substantially cylindrical body to be obtained.

Evacuated panels, and particularly those made with plastic materials, are being increasingly used in all the fields wherein thermal insulation at temperatures lower than about 100 °C is required. As examples of applications can be mentioned the walls of domestic and industrial refrigerators, of the drink dispensing machines (wherein thermal insulation is required above all in order to separate the portion of the hot drinks, generally at about 70 °C, from that of the cold drinks) or of the containers for isothermal transportation, for instance of cold or frozen drugs or food. Further, applications of these panels in the building field or in the car industry are being studied.

As is it known, an evacuated panel is formed of an envelope, having generally a thickness of some tens or hundreds of micrometers, wherein a filling material having a thickness between some millimeters and some centimeters is provided.

The heat transport between the two faces of the panel is due to the sum of four main phenomena, namely conduction in the filling material; convection due to the presence of gas traces in the panel; radiative transport inside the panel; and finally conduction in the sheet or sheets which form the envelope, known in the field as "skin effect", possibly through the thermal bridge which is formed at the edge of the panel at the welding zones of said sheets.

The envelope has the function of preventing (or reducing as much as possible) the entrance of atmospheric gases inside the panel, so as to reduce the contribution of convection to the total heat transport. To this purpose, the envelope is made with so-called "barrier" sheets, characterized by having gas permeability being as low as possible, which can be formed of a single component but more frequently are multi-layers of different components. In the case of the multi-layers the barrier effect is conferred by one of the component layers,

whereas the other layers generally have functions of mechanical support and protection of the barrier layer. The most potent barrier effect is obtained by inserting a metal sheet (generally aluminum having a thickness of about 4-10 μm) between two or more sheets of plastic material; since the metals are good heat conductors, the thickness of the aluminum layer is determined by the compromise between the need of maximizing the barrier to the gas entrance and that of minimizing the skin effect.

The filling material has the function of spacing apart the two opposite faces of the envelope when vacuum is created in the panel. This material can be inorganic, such as silica powder, glass fibers, aerogels, diatomaceous earth, etc., or organic, such as rigid foams of polyurethane or polystyrene, both in the form of boards and of powders. The filling material must be anyway porous or discontinuous, so that the porosities or the interstices can be evacuated. The thickness of the filling material (and therefore of the panel) is determined by the required features of insulation: a better insulation is obviously obtained with higher thickness values of the filling material. Since the permeation of traces of atmospheric gases into the panel is practically unavoidable, these panels contain in most cases also one or more materials (generally referred to as getter materials) capable of sorbing these gases so as to maintain the pressure inside the panel at the desired values.

The known evacuated panels are rigid, and generally have a planar conformation. However, in a number of applications it would be desirable to use these panels, but the surfaces which have to be insulated are curved, and mainly cylindrical. In some of these applications the insulating material can be applied externally and in sight, like in the case of the piping for transportation of a fluid having a temperature different from the room temperature, for example pipings for air-conditioning or heating, or for the fluid transport in industrial plants. Alternatively, the insulant can be placed inside an interspace, like in the case of the bath-heaters, of the containers such as Dewar or thermal bottles, or of the pipings used for oil transportation in the arctic regions.

One of the methods used up to now for carrying out the thermal insulation

of bodies having non-planar surfaces consists in connecting several plane panels to each other, for example by sticking together the edges thereof by means of a glue, so as to obtain a composite structure which can be bent along the junction lines so as to adapt it to the shape of the body which has to be insulated. This solution is however not very satisfying, because the assembly of the panels does not contact closely (with the exception of a few points) the surfaces which have to be insulated and, in addition to this, heat transfers take place at the junctions, with the result of a scarce efficiency of thermal insulation.

Patent application WO 96/32605 in the name of the British company ICI describes a method for manufacturing rigid evacuated panels having a non-planar shape. The method consists in making in the filling material (a board of a polymeric foam having a thickness equal to that of the desired panel), prior to the evacuating step, grooves arranged in the desired direction and having suitable width and depth. Subsequently, the filling material is inserted into an envelope and the assembly is subjected to the evacuating step. Finally, the evacuated panel is sealed. At the first air exposure, the envelope is forced by the atmospheric pressure to adhere to the surface of the grooves; due to the tensile forces which are exerted on the envelope, the panels bend along the grooves and take on the final non-planar shape. By means of a series of parallel and rather close grooves, the resulting shape of the panel is nearly cylindrical.

However, this method has a number of drawbacks. First, the thickness of the panel is not regular in all the parts thereof, being lower at the bending lines, with the result of reduced thermal insulation properties along these bending lines. Second, following to the tensile stress exerted at the grooves, breakings, also microscopic, can be created in the envelope and become preferential channels for the permeation of gases towards the inside of the panel, thus permanently compromising the properties of thermal insulation of the panel itself. Further, the shape, size, distances and reciprocal positioning of the grooves fixedly determine the final shape of the non-planar panel, so that these panels have to be specially produced for every single application. Finally, the curving of these panels takes place at the first exposure to air, and therefore during the manufacturing process

or immediately after that: consequently these panels have, as soon as they are manufactured, a notable overall size which makes unprofitable their storage and transport.

Therefore, object of the present invention is providing an evacuated panel for the thermal insulation of bodies having a cylindrical curved lateral surface, which is free from said drawbacks. Said object is obtained by an evacuated panel whose main features are specified in the first claim and other features are specified in the following claims.

The advantages and features of the panel according to the present invention will become clear to those skilled in the art from the following detailed description of one embodiment thereof with reference to the accompanying drawings, wherein:

- Figure 1 shows an example of cylinder according to the broad geometrical definition thereof;
- Figure 2 shows a right cylindrical body obtained from Figure 1, which can be thermally insulated by means of a panel according to the invention;
- Figure 3 shows a cutaway view of an evacuated panel according to the present invention in its planar form;
- Figure 4 schematically shows a geometrical requirement which has to be met by the panels according to the invention;
- Figures 5 and 6 show in perspective examples of application of the panels according to the invention.

The panels according to the invention differ from those according to the prior art because they make up the required total insulating thickness rolling a panel having a low thickness at least twice around the body which is to be insulated.

This new configuration brings about a number of advantages. First, in a traditional panel the environmental heat is propagated to the external sheet which forms the envelope and, through the edge of the panel, to the envelope sheet in contact with the body which is to be insulated. On the contrary in the panels

according to the invention the portion in contact with the environment transmits heat through the envelope to a subsequent layer of the rolled panel. Therefore, the heat must cover a spiral path along the lower face of the panel in before reaching said body which is to be insulated. In this way, the skin effect is largely reduced to negligible values as a contribute of heat conduction between the two faces of the panel.

Further, with the panels according to the invention the insulation thickness is obtained as a multiple of the constant thickness of the panel, thus avoiding the grooves of patent application WO 96/32605 which represent zones having a reduced thickness and therefore of higher thermal conductivity between the two faces of the panel. Further, with respect to the panels of application WO 96/32605, in the evacuated panels according to the present invention the several small creases formed on the internal side of the envelope during the curving cannot, because of their small entity, cause a breaking of the envelope itself and therefore a permeation of atmospheric gases towards the inside of the panel.

Finally, further to these advantages of thermal insulation, the evacuated panels of the present invention are manufactured, stored and transported to the place of final application in the plane form, with notable gain of space and costs; each panel is then rolled and fastened around the body to be insulated at the time and place of the effective use.

Some geometrical definitions and conditions, relevant for the understanding of the invention, are reported in the following with reference to figures 1 and 2.

The term "cylinder" (and the terms therefrom derived) will be used in the present invention in the broadest meaning thereof, shown in figure 1, that is the surface S determined by a straight line R intersecting a plane P with an angle α and moving parallely to itself along a close curved line C laying on said plane P.

Figure 2 shows a generic solid body 1 which can be thermally insulated by means of a panel according to the present invention: this solid body has a lateral wall S' which is formed of a portion of the cylindrical surface S of figure 1 having length L, and two bases which have the curve C' as their perimeter; said two bases are defined by the intersection of surface S with two parallel planes, shown in this

case perpendicular to straight line R, so that curves C and C' are equal in the case that angle α is 90°. Body 1 can be solid, but in the common applications of the evacuated panels can be internally empty, for example in the case of a container or a piping for fluids.

The most important practical application of the panels according to the invention is for thermally insulating bodies whose lateral wall S' is a portion of surface S obtained when angle α is equal to 90° and curve C' is a circumference (the common said cylinders).

With reference to figure 3, evacuated panel 2 according to the present invention is shown to be formed in a known way of a filling material 3 closed inside an envelope 4, for example multi-layer. Panel 2 has the shape of a parallelepiped having a very reduced thickness, h, and lateral dimensions l_1 and l_2. The shape can be conferred to the panel by the filling material when it is a board, for example of a polymeric foam. In the case that the filling material does not have its own shape (powders), the panel is shaped during the manufacture, by introducing the powder in an envelope, evacuating the envelope while it is kept in a suitable die, and by finally sealing the open edge of the envelope so as to form the final envelope; the shape conferred by means of the die is then maintained because of the external pressure exerted through the envelope on the powders, thus keeping them compact. Preferred for the purposes of the invention is the use as filling material of boards of polymeric foams, particularly the open cell rigid polyurethane, well known in the field of evacuated panels.

Particularly suitable for the manufacture of envelope 4 are the multi-layer sheets, which generally comprise at least one layer, having a relatively high thickness, of a polymeric material provided with good mechanical features, particularly plasticity, which forms the mechanical support of the multi-layer; at least one layer of a material having barrier properties towards atmospheric gases, which can be polymeric or inorganic, preferably a metal and even more preferably aluminum; and at least another polymeric layer, as a covering and mechanical protection for the barrier layer. Multi-layers formed of five, six or even more layers laid one over the other are also common. The manufacture of the envelope

starting from these is generally made by heat-sealing, by techniques known in the field.

In order to guarantee a duration of at least fifteen years, the panels according to the invention preferably contain one or more getter materials, that is materials capable of chemically sorbing moisture and other atmospheric gases. Preferred is the use of getter systems with two or three getter materials, containing at least one moisture chemical sorber and at least one component selected among a transition metal oxide (having mainly the function of sorbing hydrogen, CO and hydrocarbons) and an alloy based on barium and lithium (having mainly the function of nitrogen sorption). Various getter systems of this kind are sold by the applicant under the name COMBOGETTER®, among which in particular systems containing a moisture sorber and powder of alloy based on barium and lithium, described in patent EP-B-769117; and getter systems containing a moisture sorber and a transition metal oxide, with the optional addition of powder of alloy based on barium and lithium, described in patent application EP-A-757920.

The thickness of the panel, h, must be such that the panel can be bent without damaging the integrity thereof. This feature depends both on the filling material of the panel, and on the foreseen application. It is generally known that it is possible to elastically deform a planar flexible body so as to curve it, by applying a force in different points thereof; said force is directly proportional to the cube of the thickness thereof and inversely proportional to the bending radius which is desired, with a proportionality constant different for each material which depends on the mechanical properties thereof. According to this relation, an increase of the curvature is obtained by applying increasing forces to an initially plane panel having a certain thickness. However, if the panel is subjected to an excessive force, it breaks. The most important parameter in determining the possibility of employing a certain panel in a certain application is the **h/r** ratio, wherein **h** is the panel thickness and **r** is the bending radius of the curve C' (which forms the cross-section of body 1): with reference to the drawing of figure 4, the panel according to the invention must be such that, in every point of the curve C', the ratio **h/r** is not higher than a given value for each filling material. It has been

found that this maximum value of the ratio **h/r** is about 0.20 for polyurethane rigid foams, about 0.18 for boards in polystyrene foams and about 0.10 for powder filling materials. As a practical example, a panel having a filling in polyurethane foam to be rolled around a body having a minimum bending radius of about 50 mm can have a maximum thickness of about 10 mm. A board of polyurethane foam having this thickness can be obtained by cutting horizontally, that is parallely to the main faces thereof, the thicker boards which are usually employed for the production of plane panels of the known kind. Alternatively, is possible to reduce the thickness of said boards by compression, according to a procedure known in the field.

The panel shown in figure 4 is suitable for being rolled at least twice around the curved lateral wall S' of a cylindrical body; therefore the two main opposite sides of said panel have the shape of a long rectangle, having sides l_1 and l_2. One of the dimensions (l_2 in the example of the drawing) is about double with respect to the length of curve C', so that it is possible to make at least two rollings around the body to be insulated. On the contrary, the side l_1 is equal to the length L of the body that has to be insulated, or to a submultiple thereof; as a matter of fact, as shown in figure 5, unless body 1 has an excessive size the thermal insulation thereof can be made with only one panel 2; alternatively, as shown in figure 6, if the size L is large (for example, if body 1 is a tube), it is preferable to make the body insulation with more panels 2', 2", 2"', ... placed side by side.

Finally, the panels according to the invention can be placed in sight, for instance in order to insulate pipings for civil applications. Alternatively, these panels can be placed inside interspaces, particularly when the difference of temperature to be kept between the surface S' and the environment is high; these conditions occurr for example in the applications of the Dewars, in thermal bottles, or in cryogenic pipings or placed in particularly cold regions, such as the arctic regions. In the case in use of an interspace, the thickness **h** of the panel, in addition to meeting the above mentioned requirements, will have to be not higher than half the thickness of the interspace.

CLAIMS

1. An evacuated panel (2) for the thermal insulation of a cylindrical body (1) of length (L) with a lateral wall (S') and two bases having as perimeter a curve (C'), said panel being provided with two substantially rectangular main faces and being formed of a flexible envelope (4) made with one or more barrier sheets which contains a discontinuous or porous, inorganic or polymeric filling material (3), wherein:
   - the thickness (h) of the panel is equal or lower than half of the required insulation thickness and is such that the ratio (h/r) between the thickness of the panel and the minimum bending radius (r) of the curve (C') is lower in every point of said curve than a value depending on the filling material of the panel; and
   - one side of the panel has a length (l_2) equal to at least twice the length of said curve (C').
2. A panel according to claim 1, wherein the filling material (3) is an open cell polyurethane foam and the ratio (h/r) is lower than about 0.20.
3. A panel according to claim 1, wherein the filling material (3) is an open cell polystyrene foam and the ratio (h/r) is lower than about 0.18.
4. A panel according to claim 1, wherein the filling material is a powder and the ratio (h/r) is lower than about 0.10.
5. A panel according to claim 1, wherein said curve (C') is a circumference.
6. A panel according to claim 1, wherein one side has a length (l_1) equal to the length (L) of the body (1), or to a submultiple thereof.
7. A panel according to claim 1, wherein the envelope (4) is made with one or more multi-layer sheets, comprising at least one layer of a polymeric material having a good plasticity; at least one layer of a material having barrier properties towards atmospheric gases; and at least another heat-sealable polymeric layer.
8. A panel according to claim 7, wherein the barrier layer is made of aluminum having a thickness comprised between 4 and 10 μm.
9. A panel according to claim 1, further containing a getter material or device.
10. A panel according to claim 9, wherein said getter device comprises at least one

moisture chemical sorber and at least one component selected among a transition metal oxide and an alloy based on barium and lithium.

Fig.1

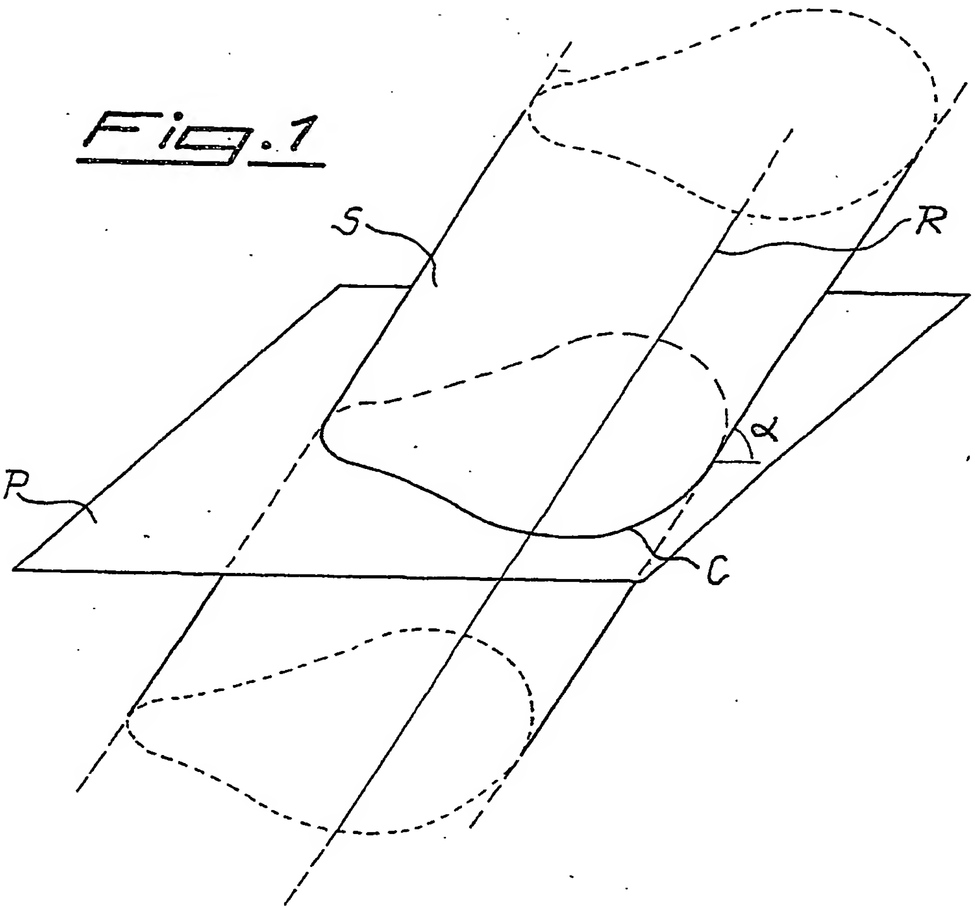


Fig.2

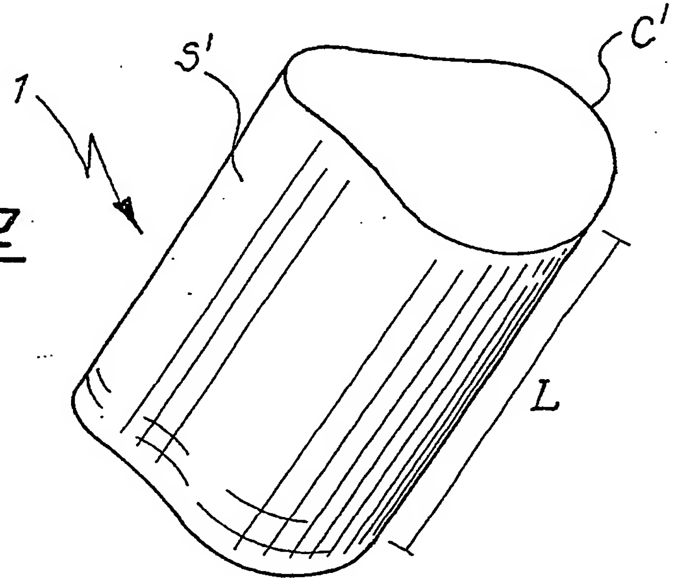


Fig. 3

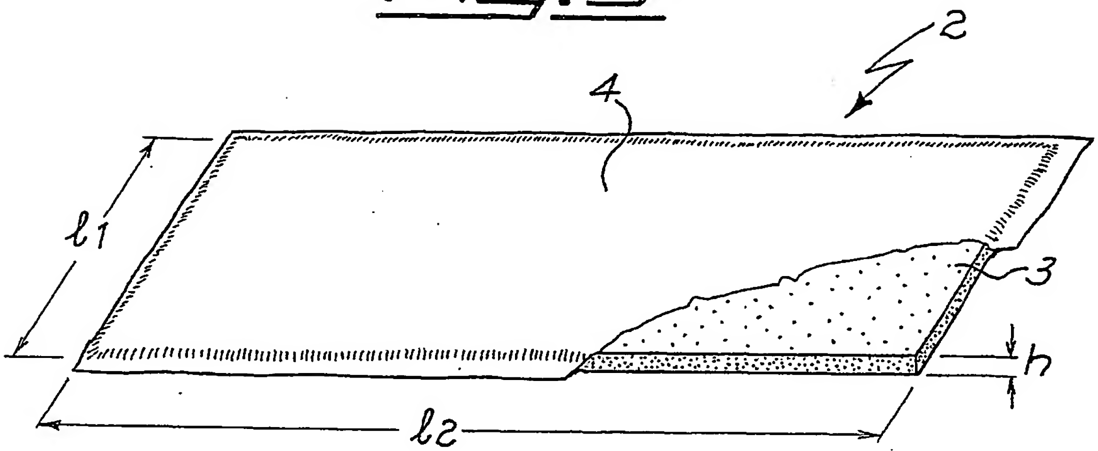


Fig. 4

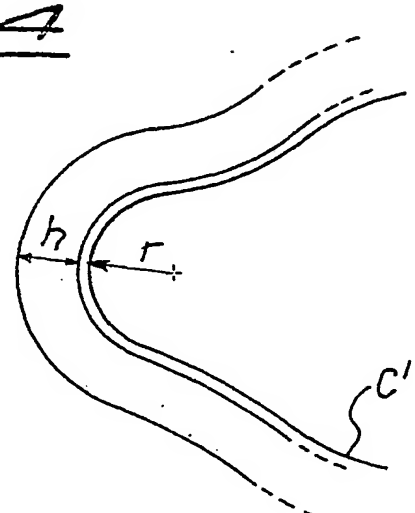


Fig. 5

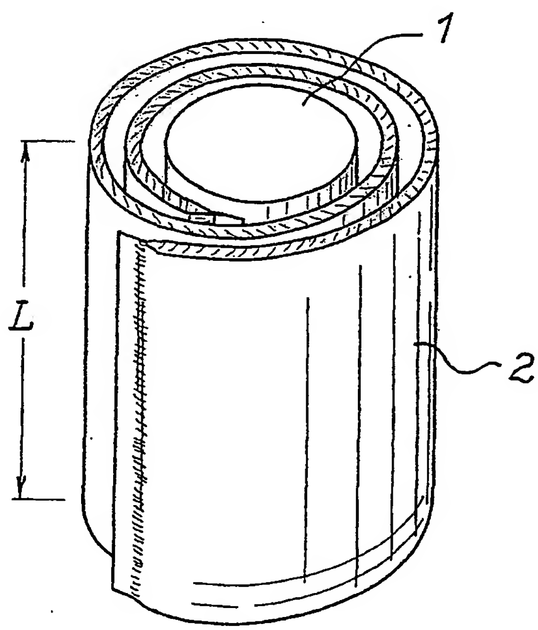
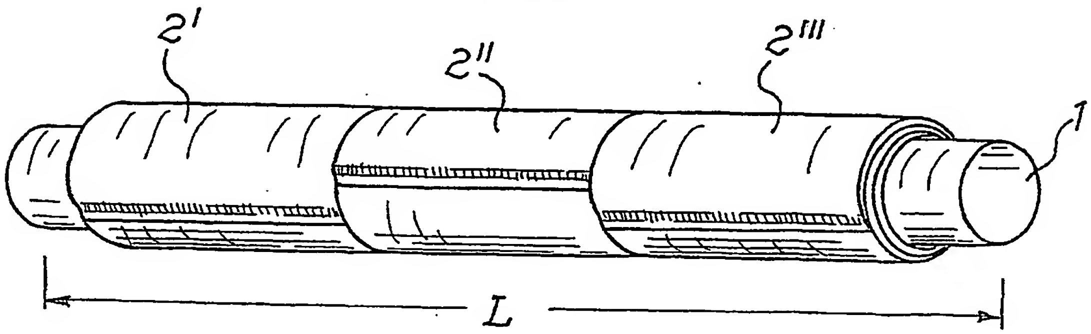


Fig. 6



INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16L59/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16L B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 937 939 A (WACKER CHEMIE GMBH) 25 August 1999 (1999-08-25) abstract; figures 3,4 page 1, line 35 - line 53	1-10
A	GB 1 297 839 A (GULF OIL CANADA LIMITED) 29 November 1972 (1972-11-29) figures 3,6 page 3, line 118 -page 4, line 11 page 6, line 24 - line 36 page 6, line 62 - line 80	1
A	US 5 843 353 A (RIK DE VOS, GUY LEON, JEAN GHISLAIN BIESMANS) 1 December 1998 (1998-12-01) cited in the application abstract; figure 1	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL – 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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